Code 455 File Copy

037230-F

THE UNIVERSITY OF MICHIGAN

AD751561

ENGINEERING PSYCHOLOGY LABORATORY

Judgments of Probability and Utility for Decision Making

Final Report

CAMERON R. PETERSON

Prepared for:

Engineering Psychology Programs
Office of Naval Research
The Department of the Navy
Arlington, Virginia
Contract No. N00014-67-A-0181-0034
NR 197-014

Approved for Public Release; Distribution Unlimited

Administered through:

September 1972

87 2 25 106

OFFICE OF RESEARCH ADMINISTRATION · ANN ARBOR

JUDGMENTS OF PROBABILITY AND UTILITY FOR DECISION MAKING

Final Report

30 September 1972

Cameron R. Peterson

Engineering Psychology Laboratory

The University of Michigan

Ann Arbor, Michigan

This research was supported by the Engineering Psychology Programs, Office of Naval Research, under Contract Number N00014-67-A-0181-0034, Work Unit Number NR 197-014.

Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) Department of Psychology University of Michigan Ann Arbor, Michigan	2a. REPORT SECURITY CLASSIFICATION Unclassified 2b. GROUP

3. REPORT TITLE

Judgments of Probability and Utility for Decision Making

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)
Final Report

5. AUTHOR(S) (First name, middle initial, last name)

Cameron R. Peterson

6. REPORT DATE 30 September 1972	7a. TOTAL NO. OF PAGES 23	7b. NO. OF REFS 0
8a. CONTRACT OR GRANT NO. N00014-67-A-0181-0034 b. PROJECT NO. NR 197-014 c. d.	9a. ORIGINATOR'S REPORT NUMBER(S) 037230-F 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report) none	

10. DISTRIBUTION STATEMENT

Approved for public release; distribution unlimited.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY Engineering Psychology Programs Office of Naval Research

13. ABSTRACT

This is a report of psychological research on decision analysis conducted between 1 October 1970 and 30 September 1972. The experimental research developed and tested procedures for eliciting assessments of probability and utility as inputs to decision analyses. One experiment on probability assessment with a known data-generating process evaluated scales and feedback as aids to the use of Bayes's theorem for revising probabilities in the light of new information. The other one evaluated the effectiveness of a scoring-rule test designed to calibrate probability assessors. There were several experiments on multi-attribute utility assessment. On-line research tested these procedures on naval problems. A handbook is being developed as a training aid to facilitate the use of these procedures. All technical reports prepared under this contract are cited in this report.

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Probabilities Utilities Subjective Probability Decision Theory Man-machine Systems Decision Analysis Information Processing						

TABLE OF CONTENTS

Introduction

What is the proper role of men and machines in decision making systems? Two competing philosophies have taken extreme positions. The first is that the role of man in intellectual systems is to do intellectual work. In particular, the role of man in a decision making system is to make decisions. However, the fact that man is in many situations a suboptimal information processor and decision maker, together with the power of the computer hardware, has led some to propose the opposite viewpoint, i.e., that man has no role at all. Thus, operations researchers have developed fully automatic systems to perform decision tasks--systems that have completely bypassed man. So we have an antinomy between fully automated systems on the one hand and, on the other, systems in which men perform the intellectual tasks while the computer keeps records, manipulates displays, and so on.

Both extreme formulations are absurd. Instead of arguing that men are superior to machines or that machines are superior to men we should be interested in the right combination of men and machines for a particular intellectual task. We have to find out what subtasks within each intellectual job men perform better, what subtasks machines perform better, and how to blend men and machines for each job.

Psychologists in the area of decision theory have developed procedures whereby men break complex problems into simple component parts, then use expert judgment to evaluate those components, and then the machine uses

rules from decision theory to combine the component assessments into a global conclusion.

One natural decomposition is into the tasks of diagnosis and decision making. Diagnosis is finding out what the situation is and decision making is choosing what to do about the situation. For diagnosis, men judge the impact of each piece of evidence and machines put the implications of those pieces of evidence together. For decision making, men evaluate the utility of the possible outcomes of each course of action, whereas machines make the actual decisions. That is, they decide which course of action to take. These particular functions are assigned to machines because we know of good algorithms for them. Bayes's theorem is the appropriate algorithm for diagnosis and the principle of maximizing expected utility is the algorithm for making decisions. Both usually require only trivial computations. But these computations depend on the proper inputs, and that is what men provide.

Man's primary inputs to the machine are estimates of utilities (numbers reflecting worth or attractiveness) and probabilities (numbers reflecting relative likelihood of occurence). These two kinds of numbers are a reflection of the principle that every decision should depend upon the answers to two questions--what is at stake and what are the odds. The problem is to find ways of eliciting suitable judgments of these numbers. That was the purpose of research conducted under this contract. The first section below describes research on probability assessment, the second describes research on utility assessment, the third describes on-line attempts to try out the results of the research on actual naval problems, and the final

section describes the initial development of a handbook designed to aid users of decision analyses.

Assessment of Probability

A Scoring Rule to Train Probability Assessors (037230-4-T).-- Two experiments showed that a test based on a proper scoring rule could improve probability assessments. The test contained three sessions of factual questions. The *Ss* indicated which of two answers was more likely to be correct for each question and then used odds assessments as an indication of how sure they were about each answer. The first and third sessions used the same set of 50 questions; *Ss* were not informed whether their answers were correct. The second session used a different set of 75 questions; *Ss* were informed whether each answer was correct and, in addition, received a score based upon a proper scoring rule (a function that increases the score earned when higher odds are assigned to the correct answer). One experiment used college students and the other used intelligence analysts. In both cases most *Ss*' earned higher scores in the third than in the first session, presumably as a result of experience with the scoring rule during the second session. This research is described in detail in the technical report.

Experiments were also conducted on response modes and probability diagrams but has not as yet yielded results that are sufficiently meaningful to write up in a technical report. Consequently, it is anticipated that research on these topics will continue next year. In addition, these two topics are included as chapters in the handbook described below.

Assessment of Utility

Multi-dimensional Value Assessment for Decision Making (037230-2-T).--Decision analysis is a tool that can be used to improve the quality of complex decisions in an uncertain environment. A decision analysis is constructed by specifying alternative courses of action and the possible consequences of action. Each of the consequences is evaluated in terms of its relative probability of occurrence and its value to the decision maker if it should occur.

Decision analysis has been used primarily in business settings where values of consequences can be measured in terms of dollars. In non-business environments, however, non-monetary criteria may be of paramount importance. The situation is further complicated if relevant values vary along more than a single dimension. This technical report reviews the psychological literature on the problem of assigning numerical values when several value attributes (or criteria) are relevant to the decision maker.

This literature is reviewed from both a descriptive and a normative point of view. That is, how do people evaluate multi-attribute objects, and how should they? A simple weighted average provides a good description of how people do, in fact, make such evaluations. The weighted average approach is also appropriate for many normative purposes and several procedures for making this evaluation process explicit are discussed and criticized.

The Application of Multi-attribute Scaling Procedures to the Development of Indices of Value (037230-1-T).-- Multi-attribute scaling procedures were applied to a non-laboratory problem--to the measurement of water quality. Several different variables (such as nitrate, fecal coloforms, turbidity and dissolved solids) contribute to water pollution. It is possible to obtain physical measures of each of the variables, but no physical model exists for combining the measures into an overall index of quality.

The multi-attribute scaling procedures were applied to this task by assessing, from water quality engineers, (1) judgments about which variables should be included in the index, (2) the type of rule for combining the variables, (3) the relative importance weights of the different variables, and (4) a curve describing the functional relation between water quality and each variable.

Water quality indices were obtained for two specific purposes--for "public water supply" and for "fish and wild-life". The experimenter used a modified Delphi procedure for obtaining concensus among the engineers for each of the indices. Even after the applications of the Delphi procedure, the engineers disagreed on the importance weights, so a sensitivity analysis applied the different indices to actual measurements on samples of river water. This analysis indicated that the disagreement about the weights was not crucial to the measurement of water quality. In fact, a major conclusion of this research is that the multi-attribute scaling procedures

are sufficiently robust so that, while great care should be used in determining the purpose for which the index will be used and in selecting variables for inclusion, relatively little time and effort need be invested in resolving small differences among quality functions and among relative weights. The technical report describes this research in detail; it is Michael F. O'Connor's PhD dissertation.

Ratio Versus Magnitude Estimates of Importance Factors (037230-3-T).--Optimal decision making requires that the decision maker trade off various goals or objectives against one another in selecting a course of action. This experiment compared two procedures for assigning importance weights to objectives. The first used magnitude estimates and the second ratio comparisons of importance. The ratio procedure produced substantially greater discrimination between the importance weights assigned to objectives than did the magnitude estimation procedure.

A sensitivity analysis revealed, however, that additive evaluation models were relatively insensitive to the differences between the importance weights produced by the two procedures. Additive models based upon the two types of weights assigned very similar overall values to alternatives. The technical report describes the research in detail.

Four Methods for Assessing Multi-attribute Utilities: An Experimental Validation (037230-6-T).-- In choosing between altervatives characterized by multiple value relevant attributes, decision makers must typically trade off one attribute against another. Previous research has shown that

as the number of attributes describing alternatives becomes large, this subjective trade-off process becomes increasingly subject to error and that decision makers tend to ignore value-relevant considerations. These shortcomings of the subjective evaluation process have been related to more general limitations on the human capacity to process information. Decomposed evaluation procedures seek to improve upon subjective evaluation by dividing the overall evaluation problem into a set of simpler subtasks, each of which is well within the judgmental capacities of the decision maker.

The first section of this technical report discusses the theoretical basis for multi-attribute value assessment and concludes that while additive evaluation models should be appropriate for most riskless decisions, non-additive models will frequently be required for decision making under uncertainty. The second section discusses the sensitivity of evalution models to assessment errors. The third section describes four procedures for constructing a decomposed evaluation model. The fourth section treats the general problem of validating evaluation procedures. And the final two sections discuss two experiments which demonstrated that all four of the decomposition procedures described can provide an appropriate measure of subjective value. This technical report is Gregory W. Fischer's PhD dissertation.

On-Line Research

Considerable time was spent with naval analysts in OP 942U during the period of this contract in an attempt to apply various procedures of

probability assessment to the problem of submarine surveillance. One of the more important results of this effort was the development of a procedure for blending historical frequency information with expert judgment in a Bayesian analysis. This procedure has now been incorporated in the Bayesian chapter of the handbook described below. The following exerpt from the 30 September 1971 annual report illustrates how beta distributions are used with this procedure.

The following actual case study is described in hypothetical terms: "a submarine has been sighted leaving the Mediterranean Sea. The analysts were attempting to infer whether or not is was a nuclear submarine; was it an SSN or an SS? The following example illustrates several procedures used for estimating this probability.

Consider the two hypotheses: the first hypothesis, (H_1), is that it is an SSN and the second hypothesis, (H_2), is that it is an SS. Some historical data are relevant to this question. Six similar submarines have been observed previously; five were SSNs and one was an SS. The task is to add that historical information to the analyst's theoretical knowledge in order to arrive at a probability estimate about this particular submarine. This estimate was achieved through the use of second-order beta probabilities and is illustrated in Figure 1. The top graph refers to the percentage of SSNs among all submarines that might be sent out. This is represented by $P(H_1)$ and is the horizontal axis of the top graph.

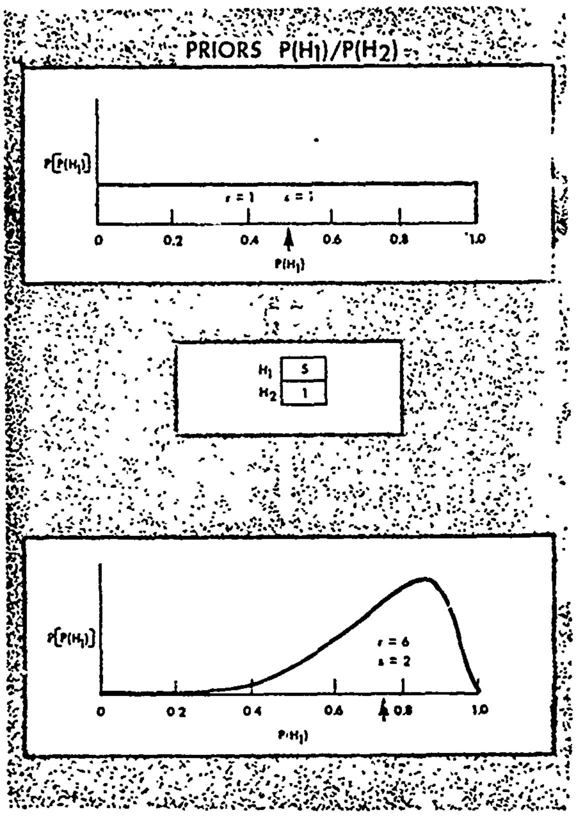


Figure 1

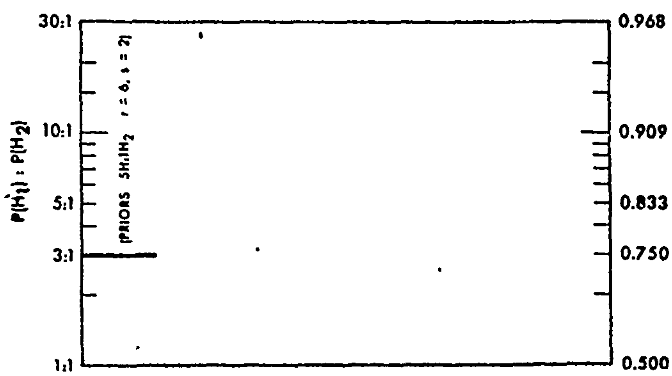


Figure 2

The horizontal function is a rectangular probability distribution estimated by an intelligence analyst. This implies that, based upon theoretical knowledge and ignoring the historical frequencies, he expects that all proportions of SSNs are equally likely. It is

just as likely that they would send 15% as 40% as 80% SSNs. It is possible, through the use of beta functions, to combine this rectangular prior probability distribution with the historical frequency information in order to obtain a posterior probability distribution. The two parameters of the prior distribution, r=1 and s=1, are simply added to the relative frequencies in order to arrive at the appropriate parameters for the posterior probability distribution: r=6 and s=2. This posterior probability distribution is displayed in the bottom portion of Figure 1. It is a probability distribution over the proportion of SSNs. The mean or expectation of this probability distribution is .75 and so that is the number we selected as the prior probability that this particular submarine was an SSN. That is the number that served as a starting point for analyzing the following data.

Figure 2 shows the logrithmic chart that was used in the experiment on Bayesian procedures described above. The line at prior odds of 3:1 indicated on the left horizontal axis and the prior probability of .75 shown on the right horizontal axis indicates the starting point derived above.

The first datum is that another submarine was sighted on a homeward-bound course. For some well-considered reasons, this datum slightly favors the hypothesis that the submarine being observed is an SSN; there is an estimated probability of .55 that this submarine would have been homeward-bound in about this time interval if the submarine being observed were an SSN; there is a 50% probability estimate if this were an SS. Therefore the likelihood ratio of the first datum, that a homeward bound submarine was observed, is .55/.50, which is equal to 1.1. This likelihood ratio is now inserted into the log odds chart as shown in Figure 3. It increases the odds in favor of an SSN by an almost imperceptible amount.

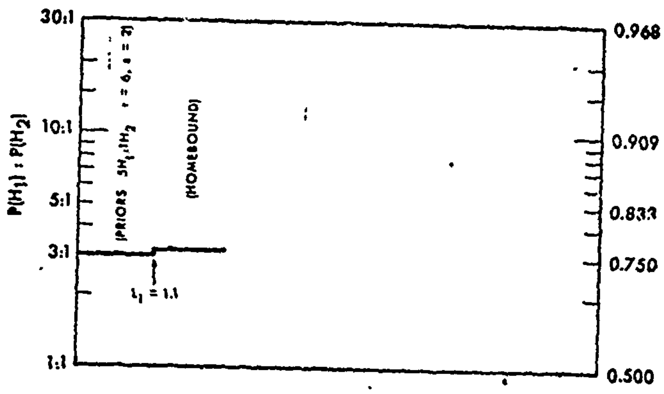


Figure 3

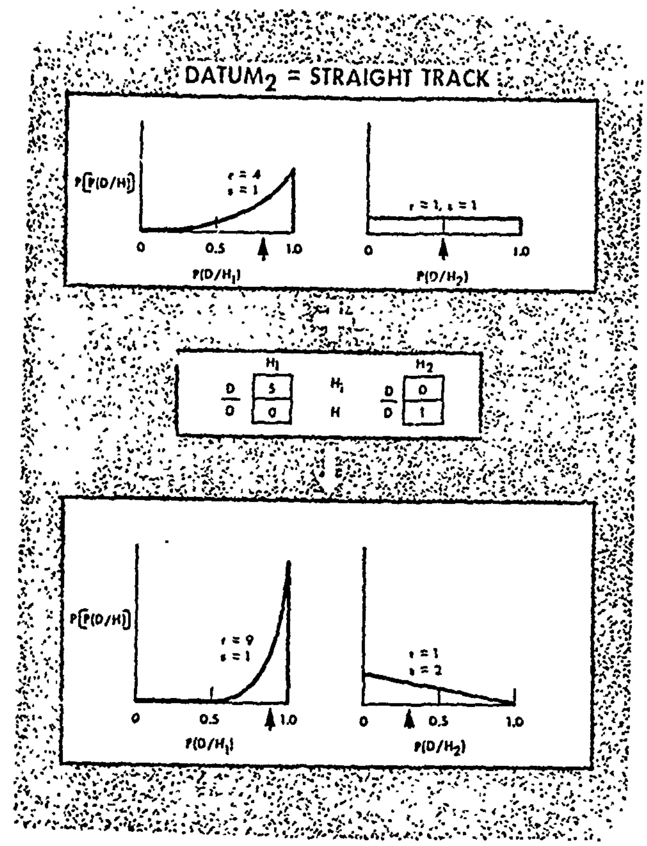


Figure 4

The second datum is that the submarine being observed seems to be following a straight track rather than taking evasive action. Figure 4 illustrates the manner in which the likelihood ratio associated with the straight track was elicited. This procedure also employed beta distributions. The upper portion of the figure refers to the prior beta distributions, ignoring historical frequencies of straight tracks. The left-hand function is the second order probability distribution over the proportion of straight tracks given an SSN as estimated by the analyst. The analyst expected that many more of the SSN, would follow straight tracks rather than evasive tracks.

The upper right-hand graph refers to the second order probability distribution for straight track given the second hypothesis, an SS. This is a uniform distribution. The middle portion of the figure shows the historical frequencies. All five SSNs previously observed had followed a straight track, whereas the one SS did not. Addition of these frequencies to the parameters of the beta distributions shown at the top of the figure imply the beta distributions shown at the bottom of the figure. The resulting likelihood ratio associated with datum 2 is therefore .90, the expectation of the bottom left-hand distribution, divided by .33. This likelihood ratio, 2.7, is now added to the log-odds chart as illustrated in Figure 5. The observation that the submarine is moving in a straight track has boosted the odds in favor of an SSN to approximately 9 to 1. This second datum is a very strong one, indeed.

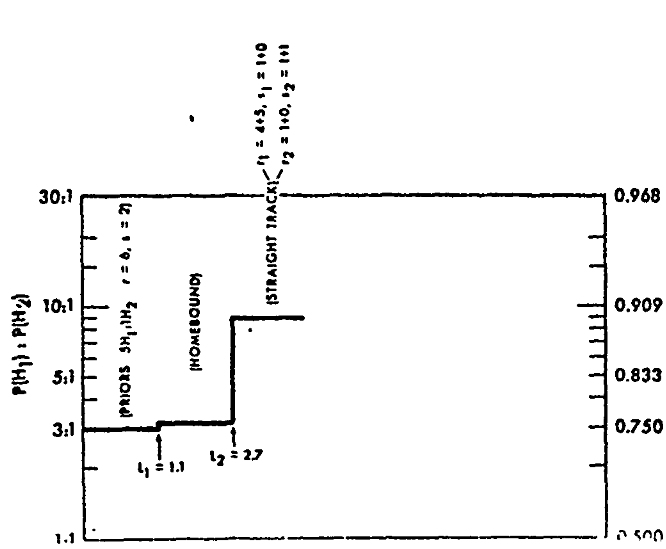
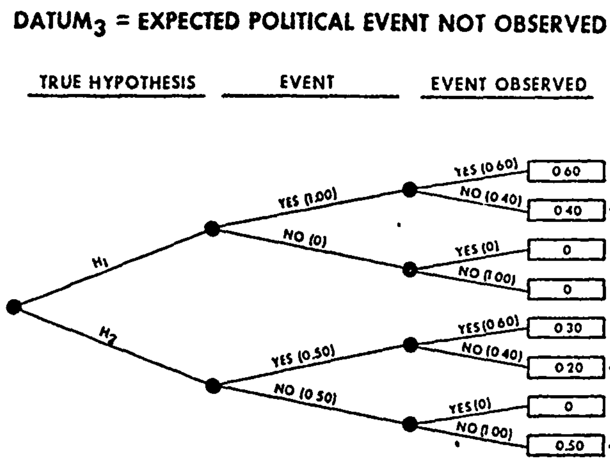


Figure 5

The analysis of the third datum is displayed in Figure 6. A political event that was expected to be observed was not observed. A conditional probability tree has been used to estimate the likelihood ratio. The left-hand branch of the tree refers to the two hypotheses, the SSN versus the SS. The next branch refers to the probability that the expected event



$$*L3 = \frac{0.40}{0.20 + 0.50} = \frac{1}{1.75}$$

Figure 6.

would occur given each of the hypotheses. The analysts estimated that the event was certain to occur if they were observing an SSN, but the probability was only .50 that it would occur given an SS. The third column of branches refers to the probability of observing the event if it occurs. The analysts reviewed some experimental literature and concluded that there was a 60% chance that they would observe the event

if it actually occurred, but it was certain that they would not observe the event if it did not occur. That is, there was no chance of a false alarm. These branch probabilities implied the path probabilities displayed in the boxes at the right-hand side of the tree. Each probability was calculated by taking the product of the component branch probabilities. Thus, the .60 in the top branch is equal to 1.0 times .6. It is now a simple matter to find the likelihood ratio. The probability of not observing the expected event given as SSN is equal to .40 (the probability of observing it if it occurs, plus zero, the probability of observing it if it doesn't occur). The probability of not observing the expected event given an SS is equal to .70, so the resulting likelihood ratio is 1/1.75.

This likelihood ratio of 1/1.75 associated with not observing an expected event is now drawn on the log odds chart in Figure 7.

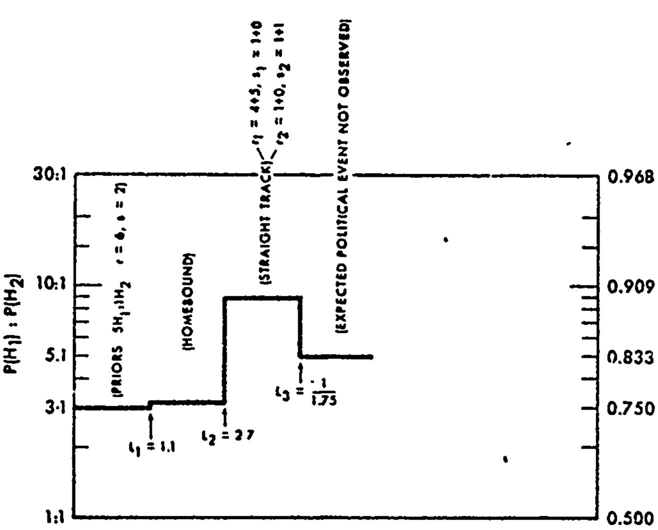


Figure 7.

It drops the odds in favor of an SSN to approximately 5 to 1.

The fourth datum is that there has been no contact with the submarine for an extended period of time. The analysts estimated a probability of 90% for an extended lack of contact with an SSN, but a probability of only 20% of no contact with the SS. Accordingly, the likelihood ratio associated with the fourth datum is .9/.2 or 4.5. This likelihood ratio is now added to the log odds chart as shown in Figure 8.

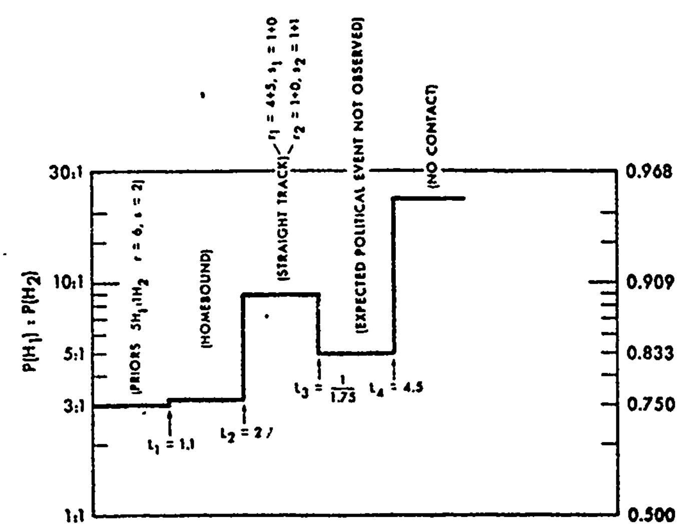


Figure 8.

It raises the odds in favor of the SSN to about 25 to 1.

The fifth datum later turned out to be a false alarm. An event has begun to develop and the analysts concluded that if it continued to develop it would favor the hypothesis that the submarine was an SS. The effect of this datum is displayed on the log odds chart in Figure 9.

Several attempts yielded no appropriate procedure for decomposing the estimate of the likelihood ratio associated with this particular event.

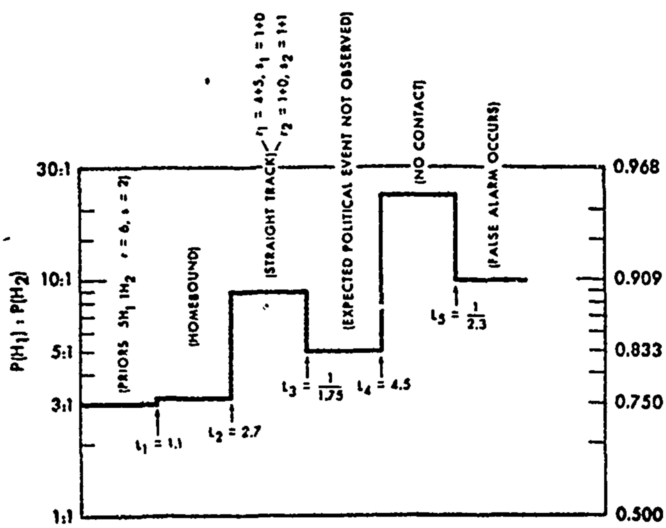


Figure 9.

Therefore, the analysts simply moved the odds on the log-odds chart on an intuitive basis. After considerable discussion, they decided that if the event did not turn out to be a false alarm, it favored the SS. It was somewhat more diagnostic than the datum of not observing the expected political event, and not quite as diagnostic as the straight track. They therefore moved the log-odds down just slightly less than they had moved it up as a function of the straight track. The resulting likelihood ratio turned out to be 2.3. The next morning, after completing this analysis, the final datum was identified as a false alarm and the odds estimates were therefore returned to about 25 to 1 as is shown in Figure 10. Some weeks later, after receiving much more information, it was

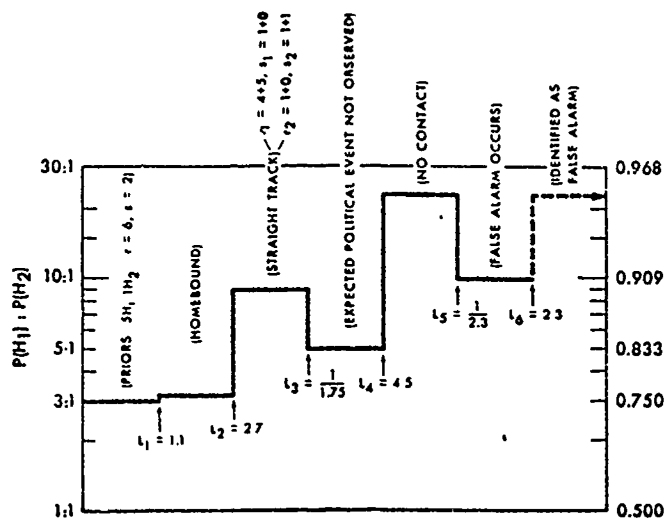


Figure 10.

concluded that this submarine was indeed an SSN. It is interesting to note that four of the analysts had discussed the problem thoroughly throughout the day and remained both uncertain and divided about which of the two hypotheses was correct. Yet the two analysts who made the estimates for this problem agreed with the final conclusion, that the data very strongly favored the hypothesis that they were observing an SSN."

In addition to providing a means of combining expert judgment and historical frequencies this procedure serves as a mechanism for calibrating analysts with respect to the assessment of likelihood ratios. That is, if

an analyst has a "feeling" for how diagnostic some historical frequency information is, and then he observes a likelihood ratio calculated by means of beta distributions, be can then use that likelihood ratio as an anchor when assessing likelihood ratios for which no historical frequencies are available.

For many problems of Bayesian inference, the linkage between observable data and the hypotheses of interest is indirect. It is then appropriate to use hierarchical or multi-stage techniques. This requires the construction of intermediate variables so that the data can be linked to intermediate variables which, in turn, can be linked to the hypotheses. We tested the feasibility of this multi-stage approach on a quite complex problem of submarine surveillance. It provided a means of handling conditional dependencies among data and also for organizing the conclusions of the analysis. That is, the hierarchical procedure aided in assessing the probabilities of the hypotheses and also in justifying those probabilities. The techniques learned in this feasability study are now being incorporated in the handbook chapter on hierarchical inference and in a Special Issue on hierarchical inference that is being prepared for Organizational Behavior and Human Performance.

Handbook for Decision Analysis

A handbook for decision analysis is being prepared for users of decision theory. Two of the chapters ("A scoring rule for probability assessment" and "Probability assessment for a continuum") are now in printed form and are

included as enclosures to this final report. This handbook is written as a collection of chapters that are relatively independent and can be read by the user of decision theory for self instruction. The motivation for such a handbook is that users (both decision makers and their staff) must understand decision analysis in order to make efficient use of that body of knowledge in order to improve the decision-making process. The problem is that most texts on the subject are overly mathematical--written for the decision theorist rather than the user.

Several chapters (numbers 6, 8, 9, 11, and 12 below) are being tested in a course on probability assessment for intelligence analysts in the State Department that began on 26 September 1972. The chapters will be modified as a result of use in this and courses in other governmental agencies designed for users of probability assessment and decision analysis. The following is a current outline of the handbook chapters.

Chapter 1 will provide a general introduction and motivation for the handbook. It will discuss the nature of the problems for which decision analysis is appropriate and also outline the book.

Chapters 2, 3, and 4 will present a ficticious case as an illustration of how decision analysis can be used on a Navy problem. This case may take place during World War II and involve a decision about whether or not a task force should be sent to a particular destination when there is a danger that enemy submarines will be encountered. It will demonstrate how nearly all

of the procedures to be described in the later chapters can be used. It is thus intended to serve as an introduction to those chapters, an introduction that will permit the reader to read through the first four chapters of the book and then go immediately to almost any of the other chapters that describe the problems or procedures with which he may be working. In order to make the reading both interesting and simple, the case will be written in the form of a dialogue between the Naval officer responsible for making the decision and a decision analyst.

Chapter 5 will present an interpretation of personalistic probabilities and the justification for their use. It will discuss the distinction between relative frequencies and expert judgment as bases for probability forecasts.

Chapter 6 will discuss elementary rules of probability theory. It will describe and explain the three basic axioms and some of the more important theorems.

Chapter 7 will discuss the relative merits of different forms of response modes that can be used when making probability estimates for categorical events.

Chapter 8 will discuss the assessment of continuous probability distributions. It will present the relative merits of using the fractile procedures (which assess areas under the curve) versus estimating density functions (which focus on the relative probabilities of specific values). It will also discuss procedures for using discrete approximations of continuous probability distributions.

Chapter 9 will discuss calibration with respect to probabilities estimated for categorical events. This chapter will provide a scoring rule test which the reader can administer to himself.

Chapter 10 will discuss calibration of continuous probability distributions. Using a definition that is analogous to the discrete case, a continuous probability distribution is well-calibrated if the area of the curve over any specified interval reflects the percentage of the time that that interval can be expected to occur.

Chapter 11 will discuss conditional assessment that will focus primarily on the use of a probability diagram to decompose a probability assessment.

Chapter 12 will discuss the revision of probabilities in the light of new evidence. It will describe Bayes's theorem, research on the conservative revision of probabilities, and procedures for overcoming such conservatism.

Chapter 13 will discuss hierarchical assessment. It will describe how Bayes's theorem can be used in a modified form when multiple stages indirectly link the observable data to the hypotheses of interest. This chapter will focus particularly upon principles to be used when constructing a hierarchical inference tree. Much of it will be based on the on-line research on submarine surveillance described above.

Chapter 14 will introduce the concept of value and show how it is used in a decision analysis.

Chapter 15 will discuss what is frequently called multi-attribute utility. It will describe procedures for reducing values that are inherently multidimensional to a single dimension.

Chapter 16 will discuss utility in its classical form as a procedure for incorporating attitude toward risk into a decision analysis. It will describe psychological procedures for eliciting utility functions.

Chapter 17 will discuss sensitivity analysis. This is a topic that is repeated throughout other chapters in the book. It will describe procedures that can be used to measure the degree to which the conclusion of an analysis is sensitive to changes in each of the inputs.

Chapter 18 will discuss principles for structuring a decision analysis. This chapter comes near the end of the hand-book rather than at the beginning because many concepts of decision theory must be well understood before a sensible discussion of structuring can be understood.

Chapter 19, the last chapter of the handbook, will discuss practical problems in the implementation and use of decision analysis in Naval organizations.

List of Technical Reports Prepared Under This Contract

037230-1-T. The Application of Multi-attribute Scaling Procedures to the Development of Indices of Value, 1 June 1972, Michael F. O'Connor.

037230-2-T. Multi-dimensional Value Assessment for Decision Making, 1 June 1972, Gregory W. Fischer.

037230-3-T. Ratio Versus Magnitude Estimates of Importance Factors, 1 September 1972, Gregory W. Fischer and Cameron R. Peterson.

037230-4-T. A Scoring Rule to Train Probability Assessors, 30 September 1972, Jane Hoffman and Cameron R. Peterson.

037230-5-T. Bayes's Theorem: Response Scales and Feedback, 30 September 1972, Patricia A. Domas, Barbara C. Goodman and Cameron R. Peterson.

037230-6-T. Four Methods for Assessing Multi-attribute Utilities: An Experimental Validation, 30 September 1972, Gregory W. Fischer.

DISTRIBUTION LIST

Director, Engineering Psychology (5 cys)
  Programs, Code 455
Office of Naval Research
800 North Quincy Street
Arlington, Virginia 22217

Defense Documentation Center (12 cys)
Cameron Station
Alexandria, Virginia 22314

Director, ONR Branch Office
Attn: Dr. C. Harsh
495 Summer Street
Boston, Massachusetts 02210

Director, ONR Branch Office
Attn: Dr. M. Bertin
536 S. Clark Street
Chicago, Illinois 60605

Director, ONR Branch Office
Attn: Dr. E. Gloye
1030 East Green Street
Pasadena, California 91106

Director, ONR Branch Office
Attn: Mr. R. Lawson
1030 East Green Street
Pasadena, California 91106

Director, Naval Research Laboratory (6 cys)
Technical Information Division
Code 2027
Washington, D.C. 20390

Director, Naval Research Laboratory (6 cys)
Attn: Library, Code 2029 (ONRL)
Washington, D.C. 20390

Office of Naval Research
Mathematical Sciences Division, Code 430
Arlington, Virginia 22217

Office of Naval Research
Aeronautics Programs, Code 461
Department of the Navy
Arlington, Virginia 22217

Dr. John J. Collins
Office of the Chief of Naval Operations
Op-987F
Department of the Navy
Washington, D.C. 20350

CDR H. J. Connery
Office of the Chief of Naval Operations
Op-987M4
Department of the Navy
Washington, D.C. 20350

Dr. A. L. Slafkosky
Scientific Advisor
Commandant of the Marine Corps
Code AX
Washington, D.C. 20380

Dr. Heber G. Moore
Hqs., Naval Material Command
Code 03R4
Department of the Navy
Washington, D.C. 20360

Chief of Naval Material
Prog. Admin. Personnel & Training
NAVMAT 03424
Department of the Navy
Washington, D.C. 20360

Bureau of Medicine and Surgery
Human Effectiveness Branch, Code 713
Department of the Navy
Washington, D.C. 20360

Mr. A. Sjoholm
Bureau of Personnel
Personnel Research Div., PERS A-3
Washington, D.C. 20370

DISTRIBUTION LIST (continued)

CDR James E. Goodson
Bureau of Medicine and Surgery
Operational Psychology Branch, Code 513
Department of the Navy
Washington, D.C. 20360

Commander Naval Safety Center
Attn: Life Sciences Department
Naval Air Station
Norfolk, Virginia 32511

LCDR Curt Sandler, MSC
Naval Safety Center
Code 811
Norfolk, Virginia 32511

CDR Robert Wherry
Human Factors Engineering Systems Ofc.
Naval Air Development Center
Johnsville
Warminster, Pennsylvania 18974

Human Factors Engineering Branch
Code 5342
U. S. Naval Missile Center
Point Mugu, California 93041

Dean of Research Administration
Naval Postgraduate School
Monterey, California 93940

Mr. E. Ramras (3 cys)
Technical Director
Personnel Research & Development Lab
Washington Navy Yard
Washington, D.C. 20390

Commanding Officer (3 cys)
Naval Personnel and Training Research Lab
Attn: Technical Director
San Diego, California 92152

Director, Behavioral Sciences Dept.
Naval Medical Research Institute
Bethesda, Maryland 20014

Commanding Officer
Naval Medical Neuropsychiatric Research Un
San Diego, California 92152

U. S. Air Force Office of Scientific Resea
Life Sciences Directorate, NL
1400 Wilson Blvd.
Arlington, Virginia 22209

Dr. J. M. Christensen
Chief, Human Engineering Division
Aerospace Medical Research Lab
Wright-Patterson AFB, Ohio 45433

Dr. J. E. Uhlaner
Director, U.S. Army Behavior and Systems Research Lab
1300 Wilson Blvd.
Arlington, Virginia 22209

Chief of Research and Development
Human Factors Branch
Behavioral Science Division
Department of the Army
Washington, D.C. 20310
Attn: Mr. J. Barber

Army Motivation & Training Lab
Rm. 239 Commonwealth Bldg.
1300 Wilson Blvd.
Arlington, Virginia 22209

Lt. Col. Austin W. Kibler
Director, Behavioral Sciences
Advanced Research Projects Agency
1400 Wilson Blvd.
Arlington, Virginia 22209

DISTRIBUTION LIST (continued)

Dr. Stanley Deutsch
Chief, Man-Systems Integration
OART, Hqs., NASA
600 Independence Avenue
Washington, D.C.

Dr. Jesse Orlansky
Institute for Defense Analyses
400 Army-Navy Drive
Arlington, Virginia 22202

Mr. Luigi Petrullo
2431 N. Edgewood Street
Arlington, Virginia 22207

Capt. Jack A. Thorpe
Department of Psychology
Bowling Green State University
Bowling Green, Ohio 43403

Dr. Sami Hassid
University of California
College of Environmental Design
Berkeley, California 94720

Dr. Eugene Galanter
Columbia University
Department of Psychology
New York, New York 10027

Dr. J. Halpern
Department of Psychology
University of Denver
University Park
Denver, Colorado 80210

Dr. S. N. Roscoe
University of Illinois
Institute of Aviation
Savoy, Illinois 61874

Dr. William Bevan
The John Hopkins University
Department of Psychology
Charles & 34th Streets
Baltimore, Maryland 21218

Dr. Ward Edwards
University of Michigan
Engineering Psychology Laboratory
Ann Arbor, Michigan 48105

Dr. Cameron Peterson
Decisions and Designs Inc.
Suite 600
7900 Westpark Drive
McLean, Virginia 22101

Dr. Irwin Pollack
University of Michigan
Mental Health Research Institute
205 N. Forest Avenue
Ann Arbor, Michigan 48104

Dr. W. H. Teichner
Department of Psychology
New Mexico State University
Las Cruces, New Mexico 88001

Dr. J. W. Black
Ohio State University
Department of Speech
154 North Oval Drive
Columbus, Ohio 43210

Dr. Edwin A. Fleishman
American Institutes for Research
8555 16th Street
Silver Sprin, Maryland 20910

American Institutes for Research
Library
135 N. Bellefield Avenue
Pittsburgh, Pennsylvania 15213

DISTRIBUTION LIST (continued)

Psychological Abstracts
American Psychological Association
1200 17th Street
Washington, D.C. 20036

Dr. A. I. Siegel
Applied Psychological Services
404 East Lancaster Street
Wayne, Pennsylvania 19087

Dr. H. M. Bowen
25 Crockett Street
Rowayton, Connecticut 06853

Dr. L. J. Fogel
Decision Science, Inc.
4508 Mission Bay Drive
San Diego, California 92112

Dr. Joseph Wulfeck
Dunlap and Associates, Inc.
1454 Cloverfield Blvd.
Santa Monica, California 90404

Dr. Robert R. Mackie
Human Factors Research, Inc.
Santa Barbara Research Park
6780 Cortona Drive
Goleta, California 9301"

Dr. W. S. Vaughan
Oceanautics, Inc.
3308 Didge Park Road
Landover, Maryland 20785

Dr. Amos Freedy
Perceptronics, Inc.
17100 Ventura Blvd.
Encino, California 91316

Dr. C. H. Baker
Director, Human Factors Wing
Defense Research Establishment Toronto
P. O. Box 2000
Downsville, Toronto
Ontario, Canada

Dr. D. E. Broadbent
Director, Applied Psychology Unit
Medical Research Council
15 Chaucer Road
Cambridge, CB2 2EF
England